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THE RIGIDITY AND STRENGTH OF FRAME WALLS

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THE RIGIDITY AND STRENGTH OF FRAME WALLS

By

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Introduction

Small frame structures have never been subjected to a thoroughgoing engineering analysis. The structural details of such buildings are for the most part governed by precedent, tradition, and carpenters' judgment without much regard for the particular requirements of a particular structure. It is true that in principle, the superiority of certain details over others is known and appreciated by good workmen and good building contractors. Convincing experimental evidence, however, is lacking not only where the superiority of certain details is known, but also where there is an uncertainty as to what is right construction. Furthermore, the ultimate results of improper construction are not fully appreciated. Realizing the need for such information, the Forest Products Laboratory, cooperating with the National Lumber Manufacturers' Association, undertook a study of construction principles and practices. A series of tests was made to determine the relative resistance of different types of frame wall construction to longitudinal thrust.

The purpose of the study reported here was to obtain a better understanding and appreciation of the principles involved in wall construction, which tend to make frame dwellings and other small frame buildings substantial structures free from excessive maintenance charges. Details of construction may vary in different localities, but the basic principles with which the builder should be concerned are in all cases the same. A knowledge of the principles discussed in this report should not only assist architects and engineers but should also help prospective home owners to appreciate what they should insist upon in the way of construction.

A house has comparatively few main parts. Of these parts, the ones that contribute most to the rigidity of the structure as a whole are the walls. Observations in numerous storm-swept areas have led to the conclusion that typical lumber-sheathed walls are adequately strong for almost any condition likely to arise as regards pressures perpendicular to them. Their resistance to end thrust, however, is more critical both from the standpoint of wind resistance and from the standpoint of keeping the building properly aligned over a period of years, thereby eliminating, or reducing to a large extent, endless annoyances and needless maintenance costs. In order to determine the amount of end thrust various types of wall construction are capable of withstanding, panels, approximating in size the side of a room, were tested with loads applied to the upper plate in the direction of their length.

Test Material and Procedure

Test Panels

Panels 9 by 14 feet were selected as representative of story heights and of sufficient length to approximate practical conditions. The equipment used for making vibration tests necessitated the reduction in the size of a few panels to 7 foot 4 inches high by 12 feet 1-5/8 inches long.

All panel frames consisted of 2 by 4-inch upper and lower plates and 2 by 4-inch studs spaced 16 inches, except at the ends of the 14-foot panels where the spacing was 12 inches from the outside edge of the end post to the center of the first stud. The end posts consisted of two 2- by 4-inch pieces spaced about 3/8 inch to which a third 2 by 4 was nailed with its 4-inch side perpendicular to the 4-inch sides of the other two. With the outside edges flush, this left a nailing ledge for lath. The frame was put together with 16d common nails, the studs being fastened to the plates by two nails through the plates into the ends of the studs. Except for the end- and side-matched material, which was nominal 6-inch stock, all sheathing boards were square-edged and 8 inches wide. Sheathing and framing were of No. 1 common well-seasoned Southern yellow pine, except for the panels tested in a green condition. Material for the panels tested green was sawn at the Laboratory direct from Southern yellow pine logs. One joint was used in each course of sheathing boards, except for the short courses in finishing out at the corners with diagonal sheathing, where no joints were used.

The wood lath were 4 feet long, spaced 1/4 inch and nailed with 3d nails. Grounds were 3/4 inch. The plaster, which was of good quality, was mixed in the proportions of 100 pounds of plaster to about 175 pounds of sand. Two coats of plaster were applied and tests were made 1 week after the application of the finish coat. Mixing and plastering were done by men furnished by a reputable firm of local plaster contractors.

Test Procedure

The lower, or sole plate, of each panel was bolted and in some cases bolted and nailed to a heavy timber which in turn was fastened to the base of the Laboratory's million-pound-capacity testing machine (fig. 1). The panel was further anchored against thrust by a stirrup from the heavy timber against which the lower plate could bear. The upper plate was also securely bolted or bolted and nailed to a heavy timber, which furnished the resistance to lateral buckling always supplied to the walls by the upper floor system. At the ends of each panel long horizontal pin-connected tie bars simulated the alining action of cross walls. Load was applied to the upper plate in a direction parallel to the length of the panel by steel cables that passed around sheaves and thence up to the movable head of the testing machine. The bearings for a shaft carrying these sheaves were attached to the large cast-iron standards that supported the fixed head of the testing machine.. The application of horizontal load to the upper plate would, of course,

induce an overturning tendency, which normally would be prevented by the upper story and roof loads. The reaction to prevent overturning in test was supplied by two vertical hold-down rods, one on each side of the panel, attached at one end to the base of the testing machine and at the other to a bearing plate on top of the heavy timber to which the upper plate of the panels were attached. Between the bearing plate and the timber were placed roller bearings to provide for free longitudinal movement of the panel. The hold-down rods were placed about 2 feet from the end of the 14-foot panels and about 1 foot from the end of the 12-foot 1-5/8-inch panels. Load was applied by raising the movable head of the testing machine at the rate of 0.211 inch per minute. Movement of the upper plate with respect to the lower plate was observed for various increments of load. Figure 1 is a diagrammatic sketch of the panel setup. The apparatus for measuring deflection consisted of a vertical board securely fastened to the lower plate and extending up past the upper plate. At its upper end it had a vertical slot in which was stretched a fine wire. A steel scale was fastened to the upper plate or to the large timber to which the upper plate was attached and deflections were read by observing with a telescope the movement of the scale with respect to the wire.

Vibration tests were made by mounting a panel on a machine table having a short horizontal throw. Panels were tested up to one million cycles at the rate of 110 per minute with a movement of the table which, with 750 pounds of dead weight distributed along the upper plate, produced deflections in the panel of 50 to 75 percent of its deflection at elastic limit.

Discussion

The results of nearly 50 tests of large wall panels are given in tables 1 and 2. In table 1 are given the results for the panels without window or door openings and in table 2 the results for the panels with openings. A description of each panel appears in the tables together with its stiffness and strength as compared with the stiffness and strength of a horizontally sheathed panel without openings. In the remarks column are given the loads at which the first plaster crack appeared in the plastered panels. A basic load-deflection curve for horizontal sheathing 8 inches wide with two 8d nails in each board at each stud crossing was obtained by averaging the curves for the first four panels given in table 1 and is shown in figure 2. While the four panels are of two sizes, the load for a given movement of the upper plate with respect to the lower plate is about the same for each size. This follows from the fact that the load for a given angular distortion is independent of the height and directly proportional to the length. How the stiffness factor in the tables was obtained is illustrated in figure 2. It is the factor by which the ordinates of the first part of the curve for any panel must be divided to reduce it to the corresponding ordinates of the base curve. For example, the curve for panel No. 5 falls along the base curve fairly well out to about a 1-inch deflection when the loads of the panel No. 5 curve are divided by 4.3. It is to be noted that while the stiffness factor given in table 1 is 4.3, the maximum load factor, which was obtained by direct comparison of maximum loads, is over 8.

Consequently, this factor is an increasing one. When the factor is a changing one, a good average factor for deflections up to 1 inch, which also corresponds to the factor for a 1/2-inch deflection, has been taken as the stiffness factor. Consider in this connection panel No. 3C. The effectiveness of its let-in braces keeps increasing. At a 1/10-inch deflection the stiffness factor is about 2.0 and at 1-inch deflection it is about 3.0. A good average figure for all deflections up to 1 inch is 2.6, which also corresponds to the factor for a 1/2-inch deflection. At maximum load a factor of 3.6 is finally reached. On the other hand, panel No. 34 has a decreasing factor. A good average value out to a 1-inch deflection is 4.2, whereas the maximum load factor is 3.5. Thus there are three types of reduced curves, one that falls directly upon the base curve, one that shows a gradual increase over the base curve, and one that shows a gradual drop from the base curve. A comparison of the stiffness and load factors in tables 1 and 2 will show the tendency of any particular curve.

In order to define what is meant by the maximum load in tables 1 and 2, it is necessary to consider the behavior of the various types of panels. In the case of panel frames covered with plaster on wood lath, there was a sudden and pronounced drop in load at a movement of the upper plate of from 3/4 of an inch to 1-1/2 inches, depending upon the member, size, and arrangement of the openings. The load at which this drop occurred was taken as the maximum load. In the case of a panel covered with both plaster and sheathing, the plaster was badly cracked under distortions of less than an inch, but no pronounced drop in load occurred until the upper plate had a movement of from 2 to 4 inches. The load at which this drop occurred was taken as the maximum load. In the case of panels covered with sheathing only, a load was reached at a distortion of from 2 to 4 inches, which either held fairly constant for increasing deflections or only fell off slightly. This load was taken as the maximum load, although in the case of horizontal sheathing particularly it is known that a higher maximum would be obtained when the distortion was great enough to permit all the boards to become tight. The tests were not continued far enough to reach this second maximum, which has no practical significance because of the enormous distortion that accompanies it. Usually the tests were stopped when a load of 20,000 pounds was reached, which accounts for the fact that for several panels the maximum strength factor is given as over 8.

Horizontal Sheathing (Panels Without Openings)

When sheathing is applied horizontally, the principal resistance to longitudinal thrust is due to the reaction couples of each pair of nails at the stud crossings. Some resistance, of course, is offered by the friction between the boards and studs and by the couples set up as the edges of the boards come in contact. The slightest shrinkage, however, almost entirely eliminates the friction, and the couples are unimportant except for relatively large distortions, since relatively large movements of the upper plate are accompanied by only small changes in height. Broadly speaking, it may be said that a horizontally sheathed panel, like any other untriangulated framework, gets its rigidity from the fixity of the joints.

Panels 9 feet high by 14 feet long, sheathed horizontally with square-edged, nominal 1 by 6-inch boards, and nailed with two 8d common nails at each stud crossing, sustained an average maximum load of 2,588 pounds applied to the upper plate in a direction parallel to the length of the panel. The movement of the upper plate with respect to the lower plate at maximum load was approximately 3 inches.

Diagonal Sheathing (Panels Without Openings)

With the boards applied diagonally there is triangulation in the panel and the nails become far more effective in offering resistance to distortion. The boards may be either in compression or in tension, according to the direction of the load applied to the upper plate. When the boards were in tension the diagonal sheathing averaged about four times as rigid as the horizontal sheathing for the panels unpierced by openings and averaged over eight times as strong. When the boards were in compression, a single test showed about seven times the rigidity of horizontal sheathing and nearly eight times the maximum load.

There are two things that could account for the difference in stiffness for the two types. With the boards in tension, the upper and lower plates were pulled away in places from the heavy timber to which each was fastened, and the giving of the plate was reflected in the horizontal movement of the upper plate. When the boards were in compression, this tendency was eliminated. Furthermore, the nailing at the joint in each course was very close to the ends of the boards. With the boards in tension, these nails had slightly less effectiveness than when the boards were in compression. In actual practice, it is quite likely that the difference in stiffness, if any, for the two types would be small.

When openings were framed into the panels, the relations were somewhat altered, since an additional factor, which has to do with the stiffness of the framing around the opening, was introduced. This will be discussed later.

At the recorded maximum load, diagonal sheathing boards in compression buckled as columns and carried the studs with them.

Figure 3, A, is a photograph of a diagonally sheathed test panel. The hold-back stirrup is shown at the lower right-hand corner. Load was applied to this panel, therefore, at the upper left-hand corner, and the boards were in tension.

Bracing (Panels Without Openings)

In order to make horizontal sheathing more rigid, various forms of bracing are used. Three types of such bracing were tried out in the series of tests. Herringbone, or bridge bracing (fig. 3, B), cut-in between the studs about midway between the lower and upper plates, was found to increase the stiffness but little (about 30 percent). The maximum load was practically uninfluenced

by such bracing. The braces were 2 by 4 inches in cross section and were nailed at an angle of about $22\frac{1}{2}^{\circ}$ to the horizontal.

Braces, 2 by 4 inches, cut-in between the studs on a line (fig. 3, C) increased the stiffness of horizontal sheathing about 60 percent and increased the strength 40 percent. The percentage increase is dependent upon the angle that the bracing line makes with the plate. Had those braces been closer to 45° with the plates, the stiffness would have been somewhat greater. As load is applied at the upper left-hand corner of the panel shown in figure 3, C, the left brace is in compression and its effectiveness is dependent upon the snugness of fit and the effectiveness of the nailing. The right brace is in tension and the pieces therefore tend to pull away easily from the studs. It is of little value in comparison with the brace in compression.

Braces let into the edges of the studs at an angle with the plates are very effective. Figure 3, D and E, show nominal 1 by 4 inch strips let into the studs at different angles to the plates. One brace in figure 3, D, is in compression and the other in tension when a longitudinal thrust is applied to the panel. Both braces act immediately and effectively, whereas with the cut-in braces there is considerable distortion before they get a good bearing. With braces as shown in figure 3, D, a horizontally sheathed panel was two and one-half times as rigid as an unbraced panel, and with the braces shown in figure 3, E, the stiffness factor was increased to about 4. The maximum load for the panels shown in figure 3, D and E, was about three and one-half times that for the unbraced panel.

Number and Size of Nails (Panels Without Openings)

When the number of nails in a horizontally sheathed panel is increased from two to three at each stud crossing, there is no increase in the reaction couples and consequently no increase in rigidity or strength. With four nails at each crossing, there is an increase in the reaction couples of approximately one-third. There is a slight increase in the friction between sheathing boards and studs that helps to increase the stiffness to approximately 40 percent more than that for panels with either two or three nails at each stud crossing.

With diagonal sheathing, increasing the number of nails to three and then to four at each stud crossing produced large increases in stiffness. It is questionable, however, whether the increased stiffness is needed.

The tests indicated that bending of the nails is the predominating factor in their lateral resistance to the loads applied to the panels. When either 10d or 12d nails were used, the stiffness was about 50 percent greater than when 8d nails were used. The increase in maximum load was about 40 percent. By increasing the size of nails from 8d to 10d the stiffness of a diagonally sheathed panel was increased about 70 percent.

End- and Side-Matched Sheathing (Panels Without Openings)

It was found that the rigidity of a panel horizontally sheathed with 6-inch end- and side-matched stock was the same as that of a panel sheathed with 8-inch square-edge stock. This follows from the fact that although the arm of the reaction couples formed by each pair of nails is reduced, the number of boards and hence the number of couples is increased in about the same proportion. Maximum load was also found to be the same in both cases.

Wood Lath and Plaster (Panels Without Openings)

It was found that lath and plaster produced a more rigid panel than did any type of sheathing or sheathing and bracing. Furthermore, when plaster on wood lath was used in conjunction with either horizontal or diagonal sheathing, there was very little increase in rigidity, but a considerable increase in maximum load. The load at which the first plaster crack appeared was about the same for all cases. When the first plaster crack appeared, the upper plate had moved about three-eighths of an inch with respect to the lower plate. The cracks opened diagonally across the panel as shown in figure 4, A. Load was applied at the upper left-hand corner of this panel and accordingly the stress on planes parallel to the direction of the cracks would be a tensile stress. The cracks are numbered in the order of their sequence.

The plaster sheet itself is extremely rigid as regards longitudinal thrust. Loads, however, come upon the frame and, in order for the plaster sheet to be effective, must be carried over from the frame to the plaster. With wood lath this is accomplished largely by the plaster keys bearing against the studs. To a minor extent the loads are also carried to the lath by the lath nails and thence to the plaster by friction.

Table 1 also gives the results for a panel (No. 25) sheathed horizontally with green lumber, plastered and allowed to stand 1 month. It had about 30 percent less rigidity than panels No. 13 and 24, which were horizontally sheathed with well-seasoned lumber.

Vibrations (Panels Without Openings)

Horizontally sheathed panel No. 20 was vibrated 50,000 cycles with a forced throw that produced a deflection of 50 to 75 percent of the deflection at an apparent elastic limit. Panel No. 21, similarly constructed but of green lumber, was vibrated 1,000,000 cycles after 1 month's seasoning. Panel No. 20 showed no loss in rigidity or strength as compared with matched panel No. 19, and the loss for panel No. 21 is only that which would be expected after the month's seasoning of green lumber. In fact, the loss was less than that exhibited by other tests, which are discussed later.

Green Lumber (Panels Without Openings)

Two panels horizontally sheathed and two diagonally sheathed were made of green lumber. They were then allowed to season indoors for 1 month. When tested they had about half the stiffness of panels made of seasoned lumber and tested immediately.

Very often the sheathing on a house may be subjected to the weather for a long period, during which time there is considerable working of the nails caused by the alternate wetting and drying of the lumber. To simulate such a condition, a horizontally sheathed panel (No. 30 in table 1) was made of seasoned lumber and was placed outside for 30 days during a period of alternate sunshine and rain. At the end of that period, it was tested and showed a loss in stiffness of about 30 percent and a loss in strength of about 20 percent.

Panels With Openings

A double 28-inch window in a diagonally sheathed panel (No. 8, table 2), reduced its stiffness from a factor of about 4 to approximately 3 and the strength factor from over 8 to 5. Let-in braces, arranged around a window as shown in figure 3, F, gave a stiffness factor of 3 when a load was applied at the upper right-hand corner.

With a double 28-inch window and a 3 by 7-foot door framed into the panel, horizontal sheathing dropped to about three-quarters of the stiffness and strength of the unpierced panel.

Figure 3, G, shows a diagonally sheathed panel with a window and door in it. Load was applied at the upper right-hand corner of this panel and the boards, therefore, were in tension. From a factor of nearly 4, the stiffness dropped to 1.4 with this arrangement and the strength from over 8 to 4. It was still twice as rigid, however, as a horizontally sheathed panel with the same openings. Tension in the boards that pass over the door frame to the double window studs throw considerable bending in window studs. This, of course, reduced the stiffness of the panel as a whole. With the position of the door and window in the panel reversed as shown in figure 3, H, the bending, which took place in the double door stud, caused a still greater reduction in stiffness. In this case load was applied at the upper left-hand corner. The panel shown in figure 3, H, had a stiffness factor of 0.8 and a strength factor of 1.3. Six-inch bevel siding applied to this type of panel with 7d box nails raised the stiffness factor for the diagonal sheathing in compression to 2.0 and for that in tension to 3.3. Strength factors were raised to 3.3 and 5.4, respectively. Horizontally sheathed panels with let-in braces around the window and door, arranged as shown in figure 3, I, gave a stiffness factor of 1.5 and a strength factor of 2.2. With the siding added, these factors were increased to 2.7 and 3.4, respectively, which compares favorably with the values for diagonal sheathing.

Plaster on wood lath gave a stiffness factor of 2.3 as compared with 0.7 for horizontal sheathing, but its strength factor was only slightly more

than double that for horizontal sheathing. Horizontal and diagonal sheathing, when used in conjunction with lath and plaster, increased the stiffness factor to 2.4 and 2.8, respectively, and the strength factors to 2.2 and 4.4. Plaster with horizontal sheathing and let-in braces arranged around the openings as shown in figure 3, I, gave a stiffness factor of 4.1, which was greater than that for the diagonal sheathing, and a strength factor of 3.6, which was somewhat smaller than that for the diagonal sheathing.

Due to concentration of stress at the corners of the openings, plaster cracks developed at relatively small loads as compared with the loads causing the first cracks in the unpierced panels. Instead of 10,000 to 12,000 pounds, the first crack occurred between 800 to 1,500 pounds. The upper plate had moved only a few hundredths of an inch when the first crack appeared, whereas with the unpierced panel this movement amounted to $3/8$ inch or more. Figure 4, B, is a photograph of panel No. 23 taken after test. Load was applied to the upper right-hand corner.

Significance

Plaster on wood lath may furnish all the rigidity necessary for most purposes under normal conditions. However, as the plaster begins to crack from shrinkage, settlement, or other causes, the rigidity of the sheathing comes more and more into play, thus in violent winds or earthquakes it is the sheathing that becomes all important in preventing complete destruction. It is logical, too, that slightly more resistance than is necessary to resist ordinary distorting influences will in the long run more than pay for itself through diminishing, if not entirely eliminating, needless annoyances and frequent maintenance costs that result from the structure getting out of alignment. Diagonal or well-braced horizontal sheathing affords far more rigidity than horizontal sheathing without bracing. Either diagonal or horizontal sheathing is important from the standpoint of insulation and also assists in distributing concentrated loads. The amount of stiffness essential to good construction is not yet known and must be determined by experience.

The old "braced-timber" frame, which originated in New England, had far more rigidity than was needed perhaps, but the hundreds of old houses still standing bear witness to the fact that rigidity went hand in hand with permanence. Today building costs prevent the use in moderately priced houses of the heavy type of construction employed then. The modern adaptation of the braced frame with its small built-up corner posts and light corner bracing or the present-day balloon frame with the studs carrying through for two stories represent a great economy of material over the old style of braced frame. The platform type utilizes shorter studs but at a slightly increased expense of material than the balloon type. Good bracing and horizontal sheathing is preferable for the platform type as shrinkage in the horizontal members may cause buckling of the sheathing if diagonal sheathing is used. Diagonal sheathing or good bracing with horizontal sheathing will still give sufficient rigidity with the balloon type.

Through a modern tendency to cut costs, bracing is often omitted and horizontal sheathing is used because it is cheaper to put on. Although the inexpensive house is not necessarily an unsound house, nevertheless, certain fundamental principles should be kept in mind so that when construction methods are employed to reduce costs the methods will be such that will result in no harm to the structure. Further, the added cost of adequate bracing is so small that it can hardly be felt in the total cost of the building.

Comparison of Fiberboard With Diagonal Wood Sheathing

A series of tests was made on frame walls sheathed with 25/32-inch fiberboard sheets, 4 by 9 feet in size, nailed to the frame with 8d common nails spaced 3 inches on centers at all vertical edges, 6 inches on centers on intermediate frame members, and approximately 5-1/3 inches on centers along upper and lower plates, which is the nailing recommended by the manufacturers. The best method of applying the fiberboard on walls with window and door openings is to use sheets as wide and full-length as possible between windows and doors and fill in above the doors and windows and below the windows, using short 2 by 4-inch studs where necessary to provide nailing along all edges of the fiberboard. In walls without openings the maximum number of full-sized sheets probably should be used, together with the necessary narrow strips to finish the covering of the wall.

The results¹ are compared with diagonal wood sheathing in the following discussion and table 3.

Diagonally sheathed panels tested without siding tend to bend the studs, particularly at door and window openings, and thereby lose much of their efficiency. This difficulty is remedied when siding is applied over the diagonal sheathing, as in common building practice. Since the larger sheets of fiberboard do not have a tendency to bend the studs under test loads, the fiberboard will receive only slight benefit from the application of siding as compared with the benefit received by diagonal sheathing. The effect of the siding on diagonal sheathing is demonstrated by the data summarized in table 3 for walls with door and window openings.

It may be noted from the data on diagonally-sheathed panels with and without siding that the rigidity factor is nearly doubled and the maximum load factor more than doubled by addition of the siding, when the sheathing is stressed in compression, which, as indicated by table 3 is the weaker direction for panels with openings. Comparison of fiberboard and diagonal wood sheathing should properly be based on the diagonal wood sheathing in combination with siding. The fiberboard-sheathed walls with openings had 84 percent the rigidity factor and 64 percent the maximum load factor of diagonally sheathed walls with siding.

¹The detailed results are given in Forest Products Laboratory report R1151 entitled "Rigidity and Strength of Frame Walls Sheathed with Fiberboard" by G. E. Hock, October 1937.

From the partial summary for wall panels without openings given in table 4, it may be computed that those sheathed with fiberboard had 86 percent the rigidity factor at 1/2-inch distortion, and less than 47 percent the maximum load factor of diagonal sheathing stressed in tension (the weakest direction for walls without openings) and without siding.

Table 3.--Comparison of strength and rigidity between wood- and fiberboard-sheathed wall panels with openings

Type of sheathing	Rigidity factor at 1/2-inch movement of upper plate	Maximum load factor	Remarks
Horizontal wood- let-in braces.....	1.5	2.2	
Horizontal wood	1.0	1.0	
Fiberboard	1.6	2.1	Reinforcing studs -- recommended nailing.
Diagonal wood	1.4	3.9	Sheathing in tension.
Do.....	1.0	1.3	Sheathing in compression.
Diagonal wood with 6- inch siding.....	3.2	5.4	Sheathing in tension.
Do.....	1.9	3.3	Sheathing in compression.

Table 4.--Comparison of strength and rigidity between wood- and fiberboard-sheathed wall panels without openings

Type of sheathing	Rigidity factor at 1/2-inch movement of upper plate	Maximum load factor	Remarks
Horizontal wood- let-in braces	3.4	3.6	Average of two.
Fiberboard.....	3.0	3.8	
Diagonal wood.....	3.5	8 ⁺	Sheathing in tension.
Do.....	7.1	7.8	Sheathing in compression.

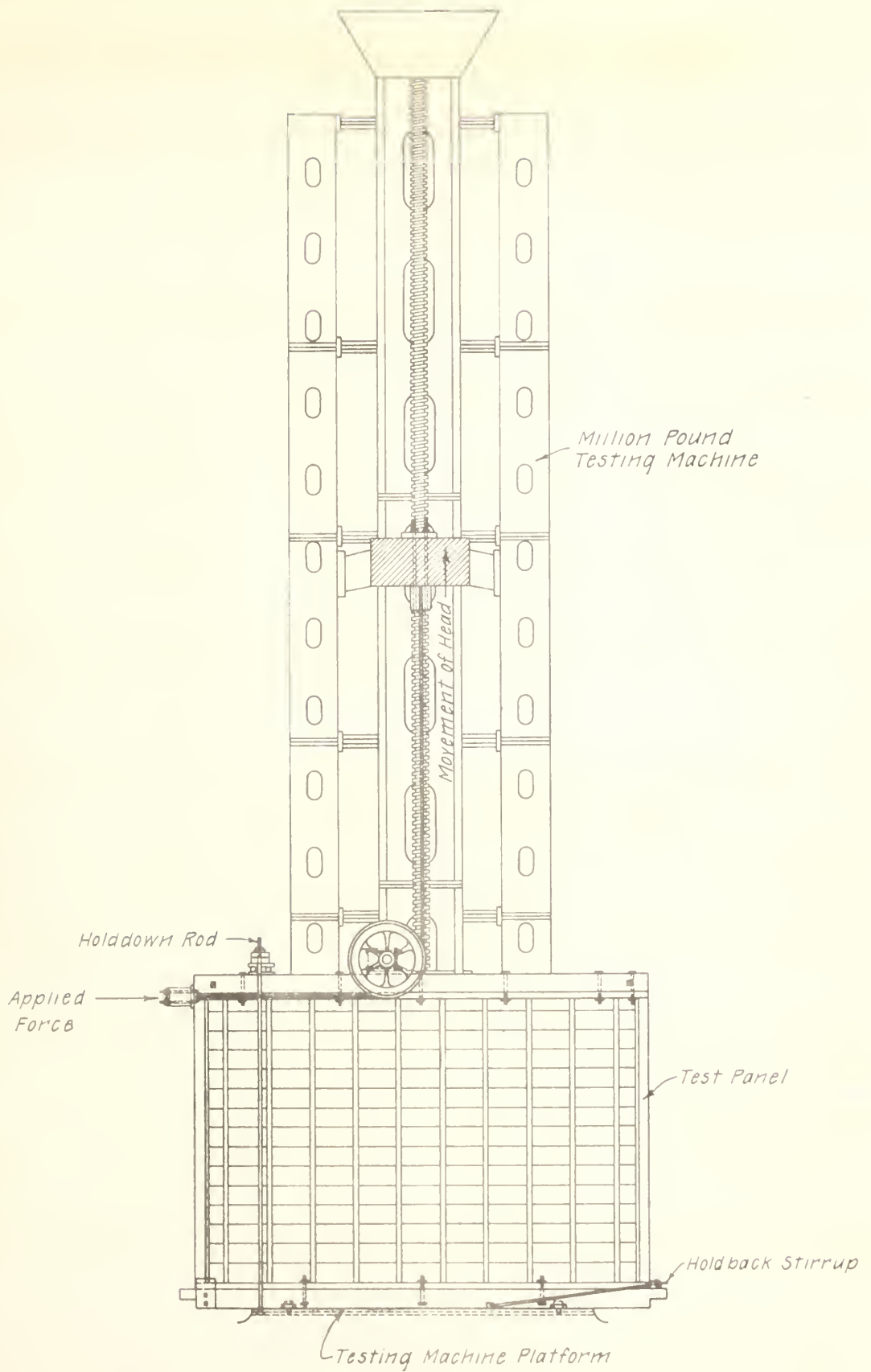


Figure 1.--Diagrammatic sketch of panel mounted for test.

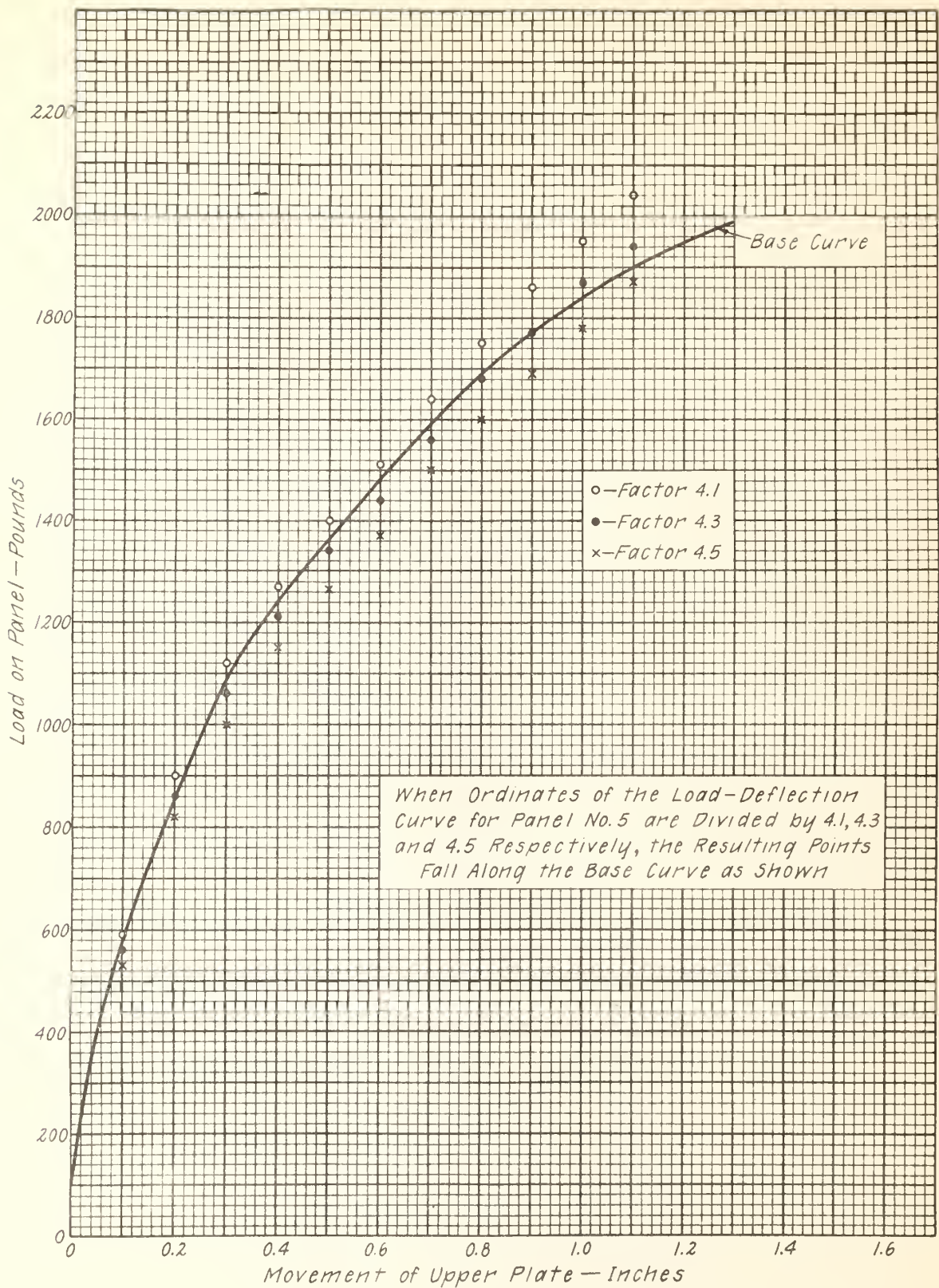


Figure 2.--Basic load-deflection curve for horizontal sheathing 8 inches wide with two 8d nails in each board at each stud crossing.

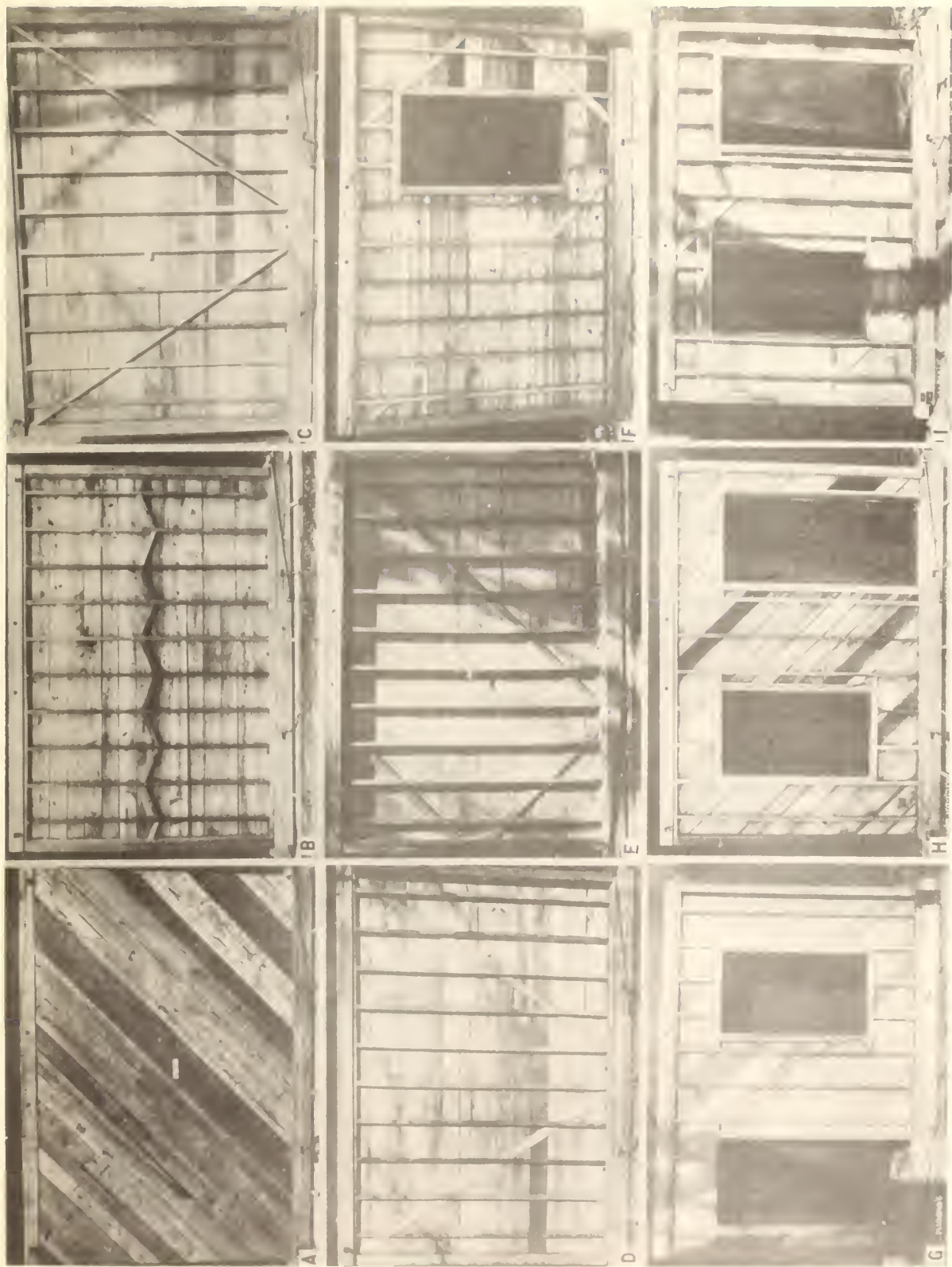


Figure 3.--Types of panels tested.

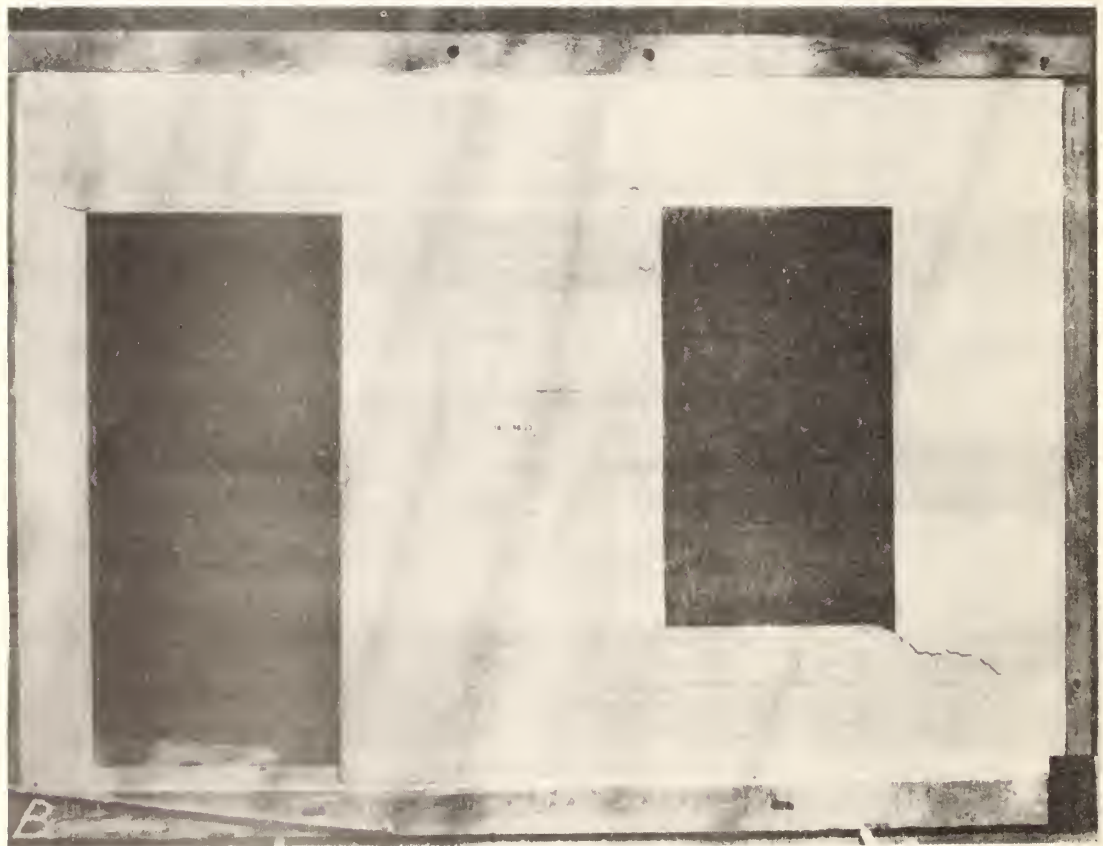
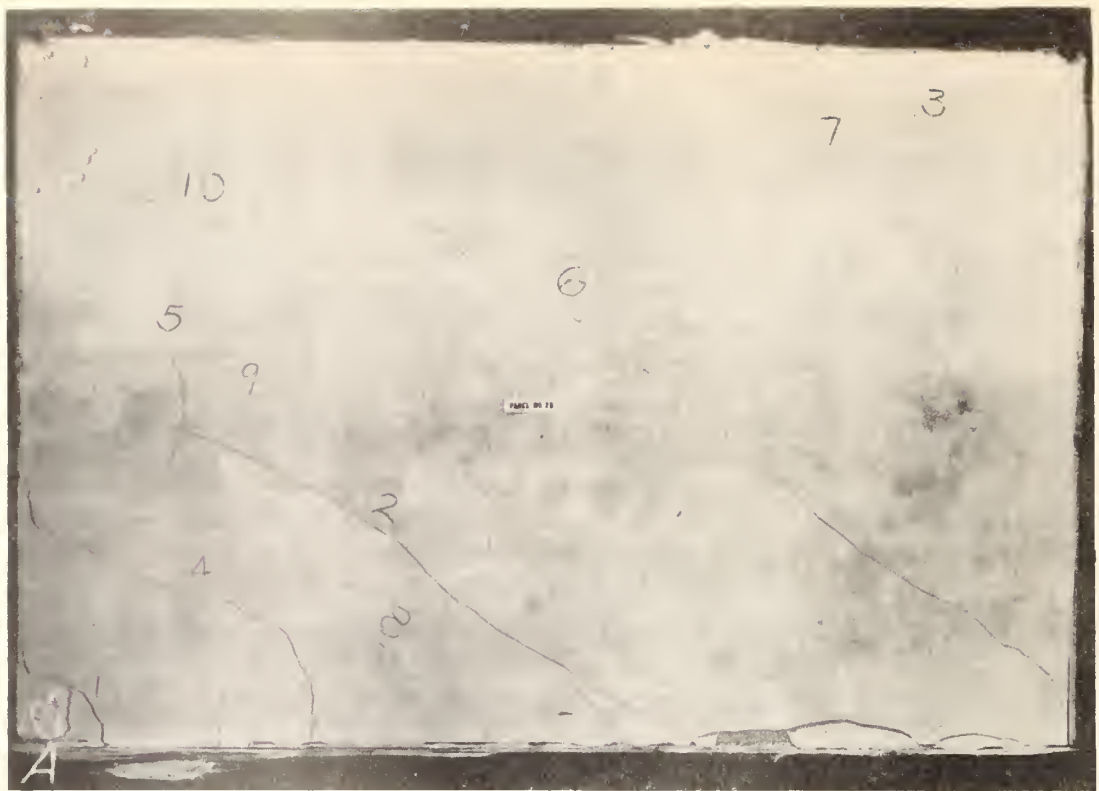


Figure 4.--Wood lath and plaster panels after test.

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